

ANALYSIS OF CCRL CONCRETE REFERENCE SAMPLE  
TO DETERMINE STRENGTH DIFFERENCES  
CAUSED BY MOLD TYPE

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STUDY MADE BY  
OREGON STATE HIGHWAY DIVISION  
MATERIALS AND RESEARCH SECTION

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## HIGHWAY DIVISION

## MATERIALS SECTION

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<b>Title</b> Analysis of CCRL Concrete Reference Sample to Determine Strength Differences Caused by Mold Type	
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<b>Abstract</b>	
<b>Key Words</b>  Cylinder Molds Strength Statistical Analysis CCRL	<b>Location</b>

ANALYSIS OF CCRL CONCRETE REFERENCE SAMPLES  
TO DETERMINE STRENGTH DIFFERENCES  
CAUSED BY MOLD TYPE

INTRODUCTION

The Oregon State Highway Division has conducted several research studies to determine the nature and extent of differences in Portland cement concrete strength caused by types of cylinder mold materials, consolidation, curing, transportation, and testing. To date, the most significant finding has been the consistent difference found between the compressive strength of cylinders cast in steel, plastic, and tin molds. The difference ranges from 5%—25%, with steel-molded cylinder being higher in strength than either plastic-molded or tin molded cylinders. The average difference is from 6%—10%. These differences have been confirmed for a number of different concrete classes and sources of materials. No cause for this difference has yet been determined, although several potential causes were evaluated and disproved. It is not known if this difference is unique to Oregon materials and test procedures, or if it is prevalent throughout the United States. The purpose of this study is to determine the extent of this problem by examining data collected by the Cement and Concrete Reference Laboratory (CCRL), National Bureau of Standards, in their routine concrete reference sample testing program.

STUDY DESIGN

As a special request, the CCRL provided the Oregon State Highway Division (OSHD) with computer disks and listings of all test data collected for concrete reference samples No. 63 and 64. The data provided included: air content, slump, unit weight, and 7-day compressive strength. Also, these data were coded by CCRL personnel to indicate: type of mixer (pan or drum), type of cylinder mold (steel, tin, plastic, or cardboard), and method of capping (elastomeric pad, high-strength gypsum, or sulfur mortar).

These data were analyzed to determine if mean differences were statistically significant at the 5% significance level. Standard methods for the "t" test of significance between two sample means were used.<sup>1</sup>

## RESULTS

### 7-Day Compressive Strength Statistical Data vs. Mold Type

Statistic	Mold Type/Sample							
	Steel		Tin		Plastic		Cardboard	
	63	64	63	64	63	64	63	64
Sample Size	15	15	4	4	123	123	19	19
Mean (psi)	3533	4088	3245	3965	3288	3766	3332	3932
Std. Dev. (psi)	346	432	216	132	310	392	336	327
Coeff. Var. (%)	9.8	10.6	6.7	3.6	9.4	10.4	10.1	8.3
Std. Error (psi)	90	112	108	66	28	35	77	75
% of Steel	100	100	92	97	93	92	94	96
t*	—	—	1.99	0.95	2.61	2.74	1.70	1.15
Sig. Level 1(%)	—	—	6	34	1	1	9	25
Sig. @ 5%?	—	—	NO	NO	YES	YES	NO	NO
Sig. @ 1%?	—	—	NO	NO	YES	YES	NO	NO

\*t statistic of difference between sample mold mean strength and steel mold mean strength

## CONCLUSIONS

For perhaps the first time, OCRL concrete reference samples have been analyzed to determine if there is a significant difference in concrete strength due to mold type. The results, although based on limited data, indicate there is a statistically significant difference between concrete strength produced by steel molds and plastic molds. The difference is significant at the 1% level. The magnitude of the difference is approximately 7% of the steel mold strength, with plastic mold strength lower than steel mold strength. These results are consistent with results presented in previous OSHD reports on this subject.<sup>2</sup>

The differences between tin and cardboard molds vs. steel molds are similar in magnitude, but the results are not statistically significant at the 5% level. This is likely due to the small number of samples for steel, tin, and cardboard molds.

It is concluded that the concrete strength difference between cylinders produced with plastic molds and steel molds is statistically significant. The difference is not limited to Oregon aggregates and test methods, and it has been verified as occurring at materials testing laboratories throughout the United States.

Additional testing should be performed to determine if the difference for tin and cardboard molds vs. steel molds is also statistically significant.

#### ACKNOWLEDGEMENTS

The author gratefully acknowledges the assistance provided by Robin K. Haupt, Supervisor, Cement and Concrete Reference Laboratory, who provided the data used in the study. Thanks are also due to Keith Sorensen, Computer and Special Studies Specialist, for his prompt and able statistical analysis of the CCRL data.

## REFERENCES

1. "Mathematical Tables from Handbook of Chemistry and Physics"  
Charles D. Hodgman, Editor in Chief, Chemical Rubber Publishing Co.,  
Cleveland, Ohio—1959
2. "Concrete Cylinder Mold Investigation Summary Report"  
Anthony J. George, W.J. Upton, and Donald E. Wence, Oregon State  
Highway Division, Materials Section, Salem, Oregon—March 12, 1987

CONCRETE REFERENCE SAMPLE PROGRAM  
REPORT FORM

TO:  
Robin K. Haupt, Supervisor  
Cement and Concrete Reference Laboratory  
Room A-365, Building Research  
National Bureau of Standards  
Gaithersburg, MD 20899

FROM:  
W.J. Quinn  
Oregon State Highway Division  
Materials and Research Section  
2950 State Street  
Salem, OR 97310  
Check here if name or  
address has changed \_\_\_\_\_

TEST RESULTS  
Report as indicated in ( )

	Sample No. 63	Sample No. 64
AIR CONTENT: percent (nearest 0.1 percent).....	<u>1.3</u>	<u>1.1</u> (1)
SLUMP: inches (nearest 1/4 inch).....	<u>2 1/2</u>	<u>2 1/2</u> (2)
UNIT WEIGHT: lbs/cu ft (nearest 0.1 pound).....	<u>149.0</u>	<u>149.7</u> (3)
COMPRESSIVE STRENGTH:	No. 63 Cyl Diam	No. 64 Cyl Diam
7-day, total load, pounds	(1) <u>90,600*</u> <u>6.02"</u>	<u>103,800</u> <u>6.01"</u>
	(2) <u>96,500</u> <u>6.02"</u>	<u>100,700</u> <u>6.01"</u>
	(3) <u>88,500</u> <u>6.02"</u>	<u>100,900</u> <u>6.01"</u>
Average (nearest 10 psi).....	<u>3260</u>	<u>3590</u> (4)

Please furnish the following information:

\*Cylinder inadvertently tested at 6 days  
not included in average.

CONCRETE MIXER:

Manufacturer Lancaster Batch Mixer Batch capacity in cubic feet 1.75

TYPE of CYLINDER MOLD:

Steel \_\_\_\_\_ Cardboard \_\_\_\_\_ Tin \_\_\_\_\_ Plastic X  
Manufacturer Jatco, Inc.

TREATMENT of CYLINDER ENDS FOR COMPRESSION TESTING:

Capping material:

Manufacturer Atlas Minerals & Chemicals, Inc. Type of material Sulfur Compound (Vitrobonc

If laboratory mixes own capping material, give the formula: N/A

Retaining plate and elastomer pad:

Manufacturer N/A

Remarks:

Mix was "over-mortered" in accordance with ASTM C192, 6.1.2 note 9(2).

Tests performed by Bruce Patterson, Alanh Vannarath, Jim Turpen Date June 17, 1987  
Tests reported by W.J. Quinn Title Engineer of Materials

## CCRL REFERENCE SAMPLE DATA

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LAB NUMBER	PLASTIC MOLDS		STEEL MOLDS		TIN MOLDS		CARDBOARD MOLDS	
	#63	#64	#63	#64	#63	#64	#63	#64
1	3220	3670						
2	2920	3250						
3	3700	4100						
4							3140	3710
5	3700	3830						
6			3560	4110				
7	3110	4160						
8							3360	3870
9	3760	4330						
10	3640	4250						
11							3500	4060
12			3940	4530				
13	3200	3930						
14	3490	4000						
15							2690	3900
16	3260	3590						
17			3120	3610				
18							3710	4320
19	3320	4020						
20	3200	3920						
21					3310	3850		
22							2900	3190
23	3290	4080						
24			3710	4330				
25							3000	3650
26	3540	3773						
27	3630	3880						
28	2990	4000						
29							3390	3990
30	3120	3200						
31	3560	4300						
32	3510	4040						
33			3780	4110				
34	3350	3940						
35			3510	3790				
36							3610	4220
37	3170	3470						
38							4010	4360
39	3200	3420						
40	3250	4040						
42	3250	4260						
43			3460	4370				
44	3550	3660						
45	INCOMPLETE DATA							
46	3270	3890						
47	3110	3860						
50	3370	4110						
51			3000	3670				
52	2880	3360						
58							3650	4260
68			3380	3830				
70	3550	4120						
71	2960	2970						
76	3800	4420						
81	3420	4060						





LAB NUMBER	PLASTIC MOLDS		STEEL MOLDS		TIN MOLDS		CARDBOARD MOLDS	
	#63	#64	#63	#64	#63	#64	#63	#64
533							3430	4160
534	3320	3800						
535	3040	3970						
537	3560	3560						
542	INCOMPLETE DATA							
552	2810	3930						
556	INCOMPLETE DATA							
565			4010	4500				
575	3080	3500						
605			3330	4200				
626	3700	3060						
634	2750	3550						
635			2980	3140				
640					2930	3860		
641							3160	3690
644	3620	3350						
655	INCOMPLETE DATA							
661	2610	3160						
675	3190	3920						
707	3870	4090						
709	3600	3700						
711	3120	2170						
712	3080	5040						
713	3070	3300						
715	3930	4650						
731	3410	4280						
740	3860	4030						
751	3270	3510						
786	3060	3940						
799	3190	3790						
800	3310	2780						
806	2810	3650						
816	2450	3810						
823	3440	4070						
825	3130	3600						
827	3000	3270						
835	3300	3930						
841	3320	3750						
851	3600	3920						
852	3600	3890						
854	2880	3640						
877	3140	3500						
894	3020	3720						
897	3340	4020						
898	3200	3230						
903	3340	3400						
906							2870	3990
915			3750	3950				
920					3320	4120		
921	3370	4190						
923	2730	3390						
926							3320	3880
934	2630	3080						
936	2980	3460						
SAMPLE SIZE	123	123	15	15	4	4	19	19
SAMPLE MEAN	3288	3766	3533	4088	3245	3965	3332	3932
STD. DEVIATION	310.05	392.31	346.82	432.77	215.79	132.29	336.18	327.46
STD ERR OF MEAN	27.96	35.37	89.55	111.74	107.90	66.14	77.13	75.12